Inside the Nucleus

1) How many neutrons are contained in a gold nucleus $^{197}_{79}Au$? [118]

$197 - 79 = 118$

2) How many neutrons are in a nucleus of $^{24}_{12}Mg$?[12]

$24 - 12 = 12$

3) Find the atomic mass number for a uranium atom that contains 92 protons and 146 neutrons. [238]

$92 + 146 = 238$

4) Calculate the gravitational force that two protons exert on each other when they are 5 fm apart. [7 x 10^{-36} N]

$m_1 = m_2 = 1.67 \times 10^{-27}\ kg$

$r = 5\ fm = 5 \times 10^{-15}\ m$

$G = 6.67 \times 10^{-11}$

$F_g = ?$

$$F_g = \frac{G m_1 m_2}{r^2}$$

$$F_g = \frac{6.67 \times 10^{-11}(1.67 \times 10^{-27}\ kg)(1.67 \times 10^{-27}\ kg)}{(5 \times 10^{-15}\ m)^2}$$

$F_g = 7.44 \times 10^{-36}\ N$ [towards each other]

$F_g \approx 7 \times 10^{-36}\ N$ [towards each other]

5) Calculate the electrostatic force that two protons exert on each other when they are 5 fm apart. [9 N]

$q_1 = 1.60 \times 10^{-19}\ C$

$q_2 = q_1$

$r = 5 \times 10^{-15}\ m$

$F_e = ?$

$$|F_e| = \frac{k q_1 q_2}{r^2}$$

$$|F_e| = \frac{8.99 \times 10^{9}(1.60 \times 10^{-19}\ C)(1.60 \times 10^{-19}\ C)}{(5 \times 10^{-15}\ m)^2}$$

$|F_e| = 9.20576\ N$

$F_e \approx 9\ N$ [Away from each other]

6) Calculate the energy equivalent for 0.0034 u of mass, in joules and in electron volts. [5.1×10^{-13} J or 3.2 MeV]

$m = 0.0034\ u$

$c = 3.00 \times 10^8\ m/s$

$E = ?$

$E = mc^2$

$E = 0.0034u\,(1.66 \times 10^{-27}\ kg/u)(3.00 \times 10^8\ m/s)^2$

converting u to kg

$E \approx 5.1 \times 10^{-13}\ J$

$MeV \rightarrow 5.1 \times 10^{-13}\ J \left(\frac{1\ eV}{1.60 \times 10^{-19}\ J}\right)\left(\frac{1\ MeV}{1 \times 10^6\ eV}\right) = 3.2\ MeV$

7) Find the energy equivalent, in electron volts, for 0.221 u. [206 MeV]

$E = ?$

$m = 0.221\ u$

$c = 3.00 \times 10^8\ m/s$

$E = mc^2$

$E = 0.221u\,(1.66 \times 10^{-27}\ kg/u)(3.00 \times 10^8\ m/s)^2$

$E = 3.30174 \times 10^{-11}\ J$

$E = 3.30174 \times 10^{-11}\ J \left(\frac{1\ eV}{1.60 \times 10^{-19}\ J}\right)\left(\frac{1\ MeV}{1 \times 10^6\ eV}\right)$

$E \approx 206\ MeV$

8) Find the mass equivalent to 250 MeV. [0.268 u]

$E = 250\ MeV$

$= 250\ MeV \left(\frac{1 \times 10^6\ eV}{1\ MeV}\right)\left(\frac{1.60 \times 10^{-19}\ J}{1\ eV}\right)$

$= 4.00 \times 10^{-11}\ J$

$m = ?$

$c = 3.00 \times 10^8\ m/s$

$E = mc^2$

$\frac{E}{c^2} = m$

$\frac{4.00 \times 10^{-11}\ J}{(3.00 \times 10^8\ m/s)^2} = m$

$m = 4.44 \times 10^{-28}\ kg$

$m = 4.44 \times 10^{-28}\ kg \left(\frac{1\ u}{1.66 \times 10^{-27}\ kg}\right)$

$m \approx 0.268\ u$

9) Find the mass defect, expressed in kilograms, and the binding energy for a carbon-12 nucleus. [1.6429 x 10^{-28} kg, 1.476 x 10^{-11} J or 92.16 MeV]

$\Delta m = ?$ $E = ?$

$\Delta m = m_{nucleons} - m_{nucleus}$

$E = \Delta m c^2$

$m_{nucleons} = 6m_p + 6m_n$
$= 6(1.007276u) + 6(1.008665u)$
$= 12.095646u$

$m_{nucleus} = m_{atom} - 6m_e$
$= 12u - 6(5.485799 \times 10^{-4}u)$
$= 11.99670852u$

$\Delta m = 12.095646u - 11.99670852u$
$\Delta m = 0.098937479u$
$\Delta m = 1.642 \times 10^{-28}$ kg

$E = 1.642 \times 10^{-28}kg (3.00 \times 10^8 m/s)^2$
$E = 1.478 \times 10^{-11}$ J

10) Sodium $^{23}_{11}Na$ has an atomic mass of 22.989 769 u. Find the mass defect for this nucleus. [0.200286 u]

$m_{NA} = 22.989769u$

$\Delta m = m_{nucleons} - m_{nucleus}$

$p = 11$
neutrons = 23 − 11 = 12

$\Delta m = 11(1.007825u) + 12(1.008665u) - 22.989769u$
$\Delta m = 0.200286u$

11) Find the binding energy for $^{23}_{11}Na$. [186.6 MeV]

$\Delta m = 0.200286u$
$c = 3.00 \times 10^8$ m/s
$E = ?$

$E = \Delta m c^2$
$E = 0.200286u \left(1.66 \times 10^{-27}\frac{kg}{u}\right)(3.00 \times 10^8 m/s)^2$
$E = 2.99227284 \times 10^{-11}$ J
$E = 2.99227284 \times 10^{-11} J \left(\frac{1 eV}{1.60 \times 10^{-19} J}\right)\left(\frac{1 MeV}{1 \times 10^6 eV}\right)$
$E \approx 187$ MeV